DECLARATION

I, Naoko Hatae of c/o SHIGA INTERNATIONAL PATENT OFFICE, GranTokyo South Tower, 1-9-2 Marunouchi, Chiyoda-ku, Tokyo, Japan, understand both English and Japanese, am the translator of the English documents attached, and do hereby declare and state that the attached English documents contain an accurate translation of the official certified copies of Japanese Patent Application Nos. 2001-287082 and 2002-270563, and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

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JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this office.

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(Title of Invention) Through Wiring Forming Method and Metal Filling Method

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[Title of the Invention] Through Wiring Forming Method and Metal Filling Method

[Claims]

[Claim 1]

A through wiring forming method in which a through wiring (22) is formed by filling metal into a through hole (11) which penetrates a substrate (10) and opens in a top surface and bottom surface of the substrate,

characterized in that after forming a metal layer (15, 55) on an inner surface of an opening of the through hole on at least one surface (13) of the top surface and bottom surface of the substrate, the substrate is inserted in a plating solution (20) stored in a plating solution bath (19) to fill this plating solution into the through hole, and then the substrate is lifted out from the plating solution with an opening of the through hole on the other surface (14) opposite to the one surface of the substrate still occluded with a sealing material (17) and the substrate is cooled.

[Claim 2]

A through wiring forming method in which a through wiring (22) is formed by filling metal into a through hole (11) which penetrates a substrate (10) and opens in a top surface and bottom surface of the substrate,

characterized in that after forming a metal layer (15) on an inner surface of an opening of the through hole on at least one surface (13) of the top surface and bottom surface of the substrate and occluding an opening of the through hole on the other surface (14) opposite to the one surface of the substrate with a sealing material (17), this substrate is housed in a decompression chamber (18), the pressure inside the decompression chamber is reduced, the substrate is inserted in a plating solution (20) stored in a plating solution bath (19) inside the decompression chamber while maintaining a state of reduced pressure, and then after pressurizing the inside of the decompression chamber to fill the plating solution into the through hole, the substrate is lifted out from the plating solution and cooled.

[Claim 3]

The through wiring forming method according to claim 1 or 2, characterized in that in the substrate inserted in the plating solution, the metal layer is formed on the inner surface of the opening of the through hole on at least one surface of the top

surface and bottom surface of the substrate as well as around the opening of the one surface.

[Claim 4]

The through wiring forming method according to claim 3, characterized in that the plating solution communicating from the through hole is padded at sites where the metal layer was formed on the inner surface of the opening of the through hole on the one surface and around the opening of the substrate which is lifted out from the plating solution, and then, a through wiring formed by solidification of the plating solution within the through holes, and a bump (23) formed by solidification of the padded sections of the plating solution, are formed unitarily by cooling the substrate.

[Claim 5]

The through wiring forming method according to claim 4, characterized in that prior to inserting the substrate in the plating solution, the metal layer around the opening of the through hole on the one surface of the substrate is patterned corresponding to a shape of the bump to be formed.

[Claim 6]

A metal filling method in which a metal is filled into a through hole (11, 25) which penetrates a work piece (10, 24),

characterized in that after forming a metal layer (15) on an inner surface of at least one end portion of both end portions of the axial direction of the through hole, the work piece is inserted in a plating solution (20) stored in a plating solution bath (19) to fill this plating solution into the through hole, and then the work piece is lifted out from the plating solution with the other end portion in the axial direction of the through hole still occluded with a sealing material (17) and the work piece is cooled.

[Claim 7]

The metal filling method according to claim 6, characterized in that in the work piece inserted in the plating solution, the metal layer is formed on the inner surface of at least one end portion of the both end portions of the axial direction of the through hole as well as a side surface of the work piece extending around the opening of the one end portion in the axial direction of this through hole, and after inserting this work piece in the plating solution within the plating solution bath but prior to cooling of the work piece, the plating solution communicating from the through hole is padded at sites

where the metal layer was formed on the opening of the one end portion in the axial direction of the through hole and around the opening of the work piece which is removed from the plating solution, and then, a filled metal section (22, 26) formed by solidification of the plating solution within the through hole, and an external metal section (23, 27) formed by solidification of the padded sections of the plating solution, are formed unitarily by cooling the work piece.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a through wiring forming method in which a through wiring is formed by filling a metal into through holes (fine holes) formed in a substrate such as a silicon substrate, and a metal filling method in which a metal is filled into through holes (fine holes) formed in a work piece.

[0002]

[Prior Art]

For example, in the case of forming through hole electrodes (via hole electrodes) in a substrate (such as a silicon substrate) in the production process of an IC chip and so forth, a plating method is typically used in which through holes for the through hole electrodes are opened in the substrate, the substrate is inserted into a plating solution (molten metal) in which a conductive metal has been solved, and immersed in that the plating solution to fill the into the conductive metal through holes.

[0003]

[Problems to be Solved by the Invention]

However, in the case of filling metal into through holes by the plating method, there are cases in which, for some reason, the plating layer concentrically grow near the through hole entrance of the substrate, thereby making it difficult for plating liquid to enter to the back of the through holes. In this case, there are problems such as the occurrence of roughness within the through holes that made it difficult to fill metal in a state free of voids.

[0004]

In cases in which the through holes are fine holes having a high aspect ratio (depth of the hole/opening diameter of the hole) in particular, since it is difficult for the plating solution to penetrate to the back of the through holes, concentrated growth of the plating layer near the through hole entrance of the substrate occurs easily, causing the problems described above to become remarkable. For example, in the case of high-density, three-dimensional mounting consisting of the stacking of silicon IC chips and so forth, although there are cases in which through electrodes (through wirings) are formed in the substrate for connecting the wiring patterns on the top and bottom of a substrate, since the through holes for through electrodes opened in the substrate are fine holes having a high aspect ratio, if through electrodes are attempted to be formed by filling metal into the through holes using the plating method described above, it is difficult to reliably form through electrodes that are free of voids.

[0005]

In consideration of the above problems, the object of the present invention is to provide a through wiring forming method in which a through wiring that is free of void is formed by reliably filling a plating solution into the entirety of a through hole which penetrates a substrate and a through wiring and a bump protruding on the substrate are formed unitarily, and to provide a metal filling method in which a metal is reliably filled into the entirety of a through hole (fine hole) is formed in a work piece.

[0006]

[Means for Solving the Problem]

The invention according to claim 1 employs, as means for solving the above problems, a through wiring forming method in which a through wiring is formed by filling metal into a through hole which penetrates a substrate and opens in a top surface and bottom surface of the substrate, characterized in that after forming a metal layer on an inner surface of an opening of the through hole on at least one surface of the top surface and bottom surface of the substrate, the substrate is inserted in a plating solution stored in a plating solution bath to fill this plating solution into the through hole, and then the substrate is lifted out from the plating solution with an opening of the through hole on the other surface opposite to the one surface of the substrate still occluded with a sealing material and the substrate is cooled.

The invention according to claim 2 employs, as means for solving the above

problems, A through wiring forming method in which a through wiring is formed by filling metal into a through hole which penetrates a substrate and opens in a top surface and bottom surface of the substrate, characterized in that after forming a metal layer on an inner surface of an opening of the through hole on at least one surface of the top surface and bottom surface of the substrate and occluding an opening of the through hole on the other surface opposite to the one surface of the substrate with a sealing material, this substrate is housed in a decompression chamber, the pressure inside the decompression chamber is reduced, the substrate is inserted in a plating solution stored in a plating solution bath inside the decompression chamber while maintaining a state of reduced pressure, and then after pressurizing the inside of the decompression chamber to fill the plating solution into the through hole, the substrate is lifted out from the plating solution and cooled.

The invention according to claim 3 is a through wiring forming method according to claim 1 or 2, characterized in that in the substrate inserted in the plating solution, the metal layer is formed on the inner surface of the opening of the through hole on at least one surface of the top surface and bottom surface of the substrate as well as around the opening of the one surface.

The invention according to claim 4 is a through wiring forming method according to claim 3, characterized in that the plating solution communicating from the through hole is padded at sites where the metal layer was formed on the inner surface of the opening of the through hole on the one surface and around the opening of the substrate which is lifted out from the plating solution, and then, a through wiring formed by solidification of the plating solution within the through holes, and a bump formed by solidification of the padded sections of the plating solution, are formed unitarily by cooling the substrate.

The invention according to claim 5 is a through wiring forming method according to claim 4, characterized in that prior to inserting the substrate in the plating solution, the metal layer around the opening of the through hole on the one surface of the substrate is patterned corresponding to a shape of the bump to be formed.

The invention according to claim 6 is a metal filling method in which a metal is filled into a through hole which penetrates a work piece, characterized in that after forming a metal layer on an inner surface of at least one end portion of both end

portions of the axial direction of the through hole, the work piece is inserted in a plating solution stored in a plating solution bath to fill this plating solution into the through hole, and then the work piece is lifted out from the plating solution with the other end portion in the axial direction of the through hole still occluded with a sealing material and the work piece is cooled.

The invention according to claim 7 is a metal filling method according to claim 6, characterized in that in the work piece inserted in the plating solution, the metal layer is formed on the inner surface of at least one end portion of the both end portions of the axial direction of the through hole as well as a side surface of the work piece extending around the opening of the one end portion in the axial direction of this through hole, and after inserting this work piece in the plating solution within the plating solution bath but prior to cooling of the work piece, the plating solution communicating from the through hole is padded at sites where the metal layer was formed on the opening of the one end portion in the axial direction of the through hole and around the opening of the work piece which is removed from the plating solution, and then, a filled metal section formed by solidification of the plating solution within the through hole, and an external metal section formed by solidification of the padded sections of the plating solution, are formed unitarily by cooling the work piece.

[0007]

In this invention, a technique is employed in which, after inserting a substrate or a work piece having a through hole in a plating solution which is composed of heated and melted conductive metal and filling this plating solution into the through hole by allowing a plating solution to flow into the through holes, the substrate or the work piece is lifted out from the plating solution with one end of the opening of the through hole still occluded with the sealing material, after which the substrate or work piece is cooled to solidify the plating solution in the through hole. In the inventions recited in claims 1 and 2, a through wiring is formed by solidifying the plating solution in the through hole. In the invention recited in claim 6, a filled metal section is formed by solidifying the plating solution in the through hole.

Since the heated and melted conductive metal is filled into through hole, defective filling caused by concentrated growth of the plating layer at the entrance of through hole in the case of a plating method (including the formation of voids as previously

described) can be avoided. In the present invention, "plating solution" refers to this heated and melted conductive metal.

[0008]

Here, as a result of the inventors of the present invention verifying the filled status of the plating solution within through holes after lifting out a substrate or a work piece formed from silicon or glass from the plating solution, merely a method is used in which a substrate or a work piece in which the plating solution has flown into and filled a through hole is simply lifted out from the plating solution with the side where the sealing material occludes an opening of the through hole is the lower end, it was found that, as a result of it being easy for the plating solution to flow out from the opening of the through hole that opens on the upper surface during lifting out of the substrate or the work piece, and the plating solution flowing out during lifting out, there are many cases in which there is insufficient filling of the plating solution during cooling and solidification. Since the amount of the plating solution contained in the through holes decreases if outflow of the plating solution occurs, as shown in FIG. 15, for example, the upper surface of the plating solution 2 within each through hole 1 ends up being slightly lower than the upper surface 4 of the substrate 3, resulting in the formation of level difference D. In addition, if this level difference is formed as shown in FIG. 15, even if, for example, bumps are attempted to be formed and bonded in a separate step on through wirings in which the plating solution has solidified, there is susceptibility to the occurrence of bonding defects between the bumps and through wirings, which can easily become a cause of defects such as incomplete electrical connections.

[0009]

The phenomenon in which the plating solution flows out from the through holes during lifting out of the substrate or the work piece from the plating solution is caused by being unable to ensure adequate wettability with the plating solution in the case of using silicon or glass to form the substrate or the work piece. That is, since there is a lack of acclimation between the inner surfaces of the through holes and the plating solution, outflow of the plating solution from the through holes occurs easily.

In the present invention, wettability with the plating solution that has been filled into through holes is ensured by a metal layer formed on the inner surface of the end of each through hole that is an upper end when the substrate or the work piece is lifted out

from the plating solution. As a result, when the substrate is lifted out from the plating solution, it is difficult for the plating solution to flow out from the openings of the through holes, thereby being able to prevent problems such as the formation of a level difference near the openings of the through holes. The metal layer is preferably formed over as a broad range as possible on the inner surface near the entrance of each through hole. If a metal layer is formed on the inner surface of both ends of each through hole, the plating solution is effectively acclimated throughout the inner surface of the through hole, thereby being effective in preventing the formation of voids and so forth within the through hole.

[0010]

According to the invention recited in claim 2, it is possible to reliably fill the plating solution into through holes (fine holes) having a high aspect ratio, and it is possible to reliably form through wirings without level difference.

In other words, after forming a metal layer around the opening of the through hole on at least one surface of the top surface and bottom surface of the substrate and occluding an opening of the through hole on the opposite surface (the other surface) with a sealing material, this substrate is housed in a decompression chamber while being in a state of reduced pressure. At this time, it is not necessarily the case that the inflow of the plating solution into the through holes of the substrate starts, but the state of reduced pressure is maintained within the through hole in which the plating solution is not flowed due to the presence of the plating solution and the sealing material which occlude the openings thereof. Therefore, by then pressurizing the inside of the decompression chamber, the plating solution is reliably filled into the through hole.

[0011]

If a metal layer is formed on the inner surface of the opening of the through hole on at least one surface of the top surface and bottom surface of the substrate as well as around the opening of the one surface (claim 3), the outflow of the plating solution from the through holes when the substrate is lifted out from the plating solution can be more reliably prevented due to the wettability of the plating solution with respect to the metal layer surrounding the openings. In addition, when the substrate is lifted out from the plating solution, by taking advantage of the formation of a layer of the plating solution along this metal layer (metal layer around the openings), grounded sections, bumps and

so forth of the wiring can be formed on the substrate by cooling and solidifying the plating solution on this metal layer. Here, grounded sections, bumps and so forth that are formed refer to those for which the plating solution is cooled and solidified after having been padded at those sites where the metal layer formed formed on the inner surface of the opening of the through hole on the one surface and around the opening of the substrate is present, and are unitarily formed with the through wirings that are solidified within the through hole. Since the grounded sections, bumps and so forth that are formed thus are continuous with the through wirings by the same type of metal as the through wirings, in comparison with the case of forming separately from the through wirings, there is the advantage of the absence of problems such as defective bonding with the through wirings. In addition, there are also no problems such as brittleness of the bonded sections (bonded sections between bumps and through wirings) caused by differences in the coefficients of thermal expansion or diffusion of materials and so forth that occur in the case the bumps and the through wirings are of different types of materials.

[0012]

For example, in the case of forming bumps, the size, shape and so forth can be adjusted according to the range of formation and so forth of the metal layer around the opening of each through hole on one surface of the substrate. When the substrate is lifted out from the plating solution, since the plating solution that remains at the sites where the metal layer is formed at the opening of each through hole and around the openings on one surface of the substrate can be padded in a peak-shape due to its surface tension and so forth, a peak-shaped bump can be obtained by solidifying the plating solution. Thus, the height, size and so forth of bumps can be adjusted by adjusting the formation range of the metal layer around the openings of through holes on one side of the substrate by patterning or other means.

[0013]

According to the metal filling method recited in claim 7, since a filled metal section formed by solidification of the plating solution within the through hole, and an external metal section formed by solidification of the padded sections of the plating solution, can be formed unitarily by cooling the work piece which has been lifted out from the plating solution, similar to the invention recited in claim 4, there is no

occurrence of problems such as defective bonding due to bonding of different types of metals or brittleness of bonded sections caused by difference in the coefficients of thermal expansion, diffusion of materials, etc.

[0014]

[Embodiments of the Invention]

The following provides an explanation of one embodiment of the present invention with reference to the drawings.

First, as one embodiment of a through wiring forming method and a metal filling method according to the present invention, an explanation is provided of a method (i.e., a through wiring forming method) of forming a through wiring and a bump which connect wiring patterns on both top and bottom surfaces of a substrate. This through wiring forming method is composed of a step in which a metal layer is formed (metallized) on the inner surface of the openings and around the openings of through holes on the top and bottom sides of a substrate (metallization step), a plating solution filling step in which a substrate on which this metallization step has been completed is placed in a plating solution (the conductive metal heated to melting) stored in a plating solution bath to fill the plating solution into through holes, and a cooling and solidification step in which through wirings and bumps are formed by solidifying the plating solution within the through holes and the plating solution padded in a protruding state on the substrate continuous with the through holes by cooling the substrate that has been lifted up from the plating solution bath after the plating solution filling step.

[0015]

(Metallization Step)

As shown in FIG. 1, a substrate 10 in which a plurality of through holes 11 for through wiring is formed is prepared and an oxide film in the form of an electrical insulating layer 12 (hereinafter, an electrical insulating layer may be referred to as an "oxide film") is formed on the entirety of the substrate 10 by thermal oxidation treatment of this substrate 10 (FIG. 2). Here, although a silicon substrate in the form of the substrate 10 is used, the substrate is not limited to this type, but rather semiconductor materials such as gallium arsenide (GaAs), insulating materials such as glass or ceramics, or synthetic resin substrates can also be used. Furthermore, the thickness of the substrate 10 is on the order of several hundred micrometers. Note that

the substrate 10 functions as a work piece recited in claim 6.

The through holes 11 are fine holes having a diameter on the order of several tens of micrometers (e.g., 50μm) that pass through the substrate 10, and are opened in a top surface 13 and bottom surface 14 of the substrate 10. The oxide film 12 formed by thermal oxidation treatment of the substrate 10 is formed not only on the top surface 13 and bottom surface 14 of the substrate 10, but also on the inner surface of the through holes 11.

Furthermore, here "top surface" refers to surface facing upward in the plating solution filling step (see FIGS. 9 through 13) to be described later (one side), while the "bottom surface" refers to the surface facing downward (other side).

[0016]

Next, as shown in FIG. 3, a metal layer 15 is formed by metal sputtering on the inner surface of the openings (inner surface of through holes in the vicinity of openings) of the through holes 11 on the top surface 13 and bottom surface 14 of the substrate 10, and around the openings of the through holes 11 on the top surface 13 and bottom surface 14.

More specifically, as shown in FIG. 4, a first layer 15a in the form of a chromium (Cr) layer having a thickness of about 300Å is first formed by sputtering, after which a second layer 15b in the form of a gold (Au) layer having a thickness of about 5000Å is layered and formed on the above first layer 15a. The metal layer 15 formed on the inner surface of the through holes 11 is formed at least about several tens of micrometers in towards the center in the axial direction of the through holes 11 from the top surface 13 or bottom surface 14 of the substrate 10.

[0017]

Furthermore, the metal layer 15 may be formed over the entire inner surface of the through holes 11, and in order to reliably fill the plating solution without causing the occurrence of voids inside the through holes 11 by ensuring wettability with the plating solution filled in the through holes 11, the metal layer 15 is preferably formed over a wide a range as possible within the through holes 11. In other words, the range of which the metal layer 15 is formed on the inner surface of the through holes 11 is at least the inner surface of the through holes 11 near the openings of the through holes 11

on the side of the top surface 13 (a range of at least several tens of micrometers from the openings of the through holes 11 towards the center in the axial direction), more preferably the inner surface in the vicinity of the openings in both the top and bottom surfaces of the substrate 10 (in other words, near both ends in the axial direction of the through holes 11; and, over a range on the order of at least several tens of micrometers from the openings of the through holes 11 towards the center in the axial direction on either end), and most preferably the entire inner surface of the through holes 11.

In addition, in the formation of the metal layer 15 using sputtering, since the metal layer 15 can be formed as long as it is formed within the range that can be reached by metal atoms as a result of sputtering, other metals may also be used in addition to the chromium and gold mentioned above.

[0018]

On the other hand, the metal layer 15 formed around the openings of the through holes 11 in the top surface 13 and bottom surface 14 are formed over a larger area than the formation range of bumps corresponding to the size of the target bumps to be formed (and may be formed entirely over the top surface 13 or top surface 14 of the substrate 10), and is patterned to size corresponding to the bump formation range in the step shown in FIGS. 5 and 6 to be described later.

Furthermore, the metal that forms the first layer 15a and second layer 15b of the metal layer 15 is not limited to the above-mentioned chromium or gold, but may also be another metal.

[0019]

Once formation of the metal layer 15 has been completed, as shown in FIG. 5, a photosensitive resist 16 is applied to the top surface 13 and bottom surface 14 of the substrate 10, and this photosensitive resist 16 is patterned by photolithography technology. Next, as shown in FIG. 6, a metal pattern (made of the metal layer 15) is formed of a shape that matches a desired bump size to be formed around the openings of the through holes 11 on the top surface 13 and bottom surface 14 of the substrate 10 by etching the metal layer 15 (first layer 15a and second layer 15b). FIG. 7 shows an example of the form of the metal layer 15 formed by patterning. As a result, the metal layer 15 of a target shape is formed around the openings of the through holes 11 on the top surface 13 and bottom surface 14 of the substrate 10 to complete the metallization

step.

Furthermore, the formation of the metal layer 15 by patterning on the top surface 13 and bottom surface 14 of the substrate 10 is not limited to matching a bump size to be formed, but rather may also, for example, be formed to a shape that matches the grounding section of pattern wiring formed on the top surface 13 and bottom surface 14, or may be formed to a shape that forms a portion of pattern wiring.

[0020]

(Plating solution Filling Step)

Following completion of the metallization step, as shown in FIG. 8, a heat-resistant film in the form of sealing material 17 (hereinafter, this sealing material may be referred to as a "heat-resistant film") is affixed to the bottom surface 14 of the substrate 10, to occlude the openings of the through holes 11 on the bottom surface 14. Next, as shown in FIG. 9, this substrate 10 is housed in a decompression chamber 18, the pressure inside the decompression chamber 18 is reduced, and the substrate 10 is inserted in the plating solution 20 stored in a plating solution bath 19 inside the decompression chamber 18 while maintaining this state of reduced pressure (see FIG. 10). Here, a vacuum pressure on the order of 10^{-3} to 10^{-5} Pa for an aspect ratio of the through holes 11 of 0.1 to 200 is suitable for the reduced pressure. In FIGS. 9 and 10, reference symbol 19a indicates heaters provided around the plating solution bath 19. Insertion of the substrate 10 into the plating solution 20 is carried out in a state in which this substrate 10 is maintained nearly horizontal by attaching a raising and lowering jig 21 installed within the decompression chamber 18 and lowering this raising and lowering jig 21.

[0021]

Furthermore, the substrate 10 attached to the raising and lowering jig 21 is raised and lowered while maintained nearly horizontal by raising and lowering of the raising and lowering jig 21, and removal of this substrate 10 from the plating solution 20 is also carried out while maintaining the substrate 10 nearly horizontal.

The sealing material 17 is not limited to a heat-resistant film, but rather may be any material that is capable of sealing the openings of the through holes 11 on the bottom surface 14 of the substrate 10, and its shape is also not limited to a constitution in which it covers the entirety of the bottom surface 14 as with the previously

mentioned heat-resistant film.

Here, although the plating solution 20 is specifically that which has resulted from the heating and melting of a gold-tin eutectic binder (Au-20 wt% Sn), the plating solution as claimed in the present invention is not limited to this. However, a combination between the metal layer (and particularly the surface layer) and the plating solution should be selected so as to adequately ensure wettability between them.

[0022]

Insertion of the substrate 10 into the plating solution 20 is carried out with the bottom surface 14 to which the sealing material 17 is affixed facing downward, and the top surface 13 facing upward, and the entirety of the substrate 10 is submerged in the plating solution 20 so that the top surface 13 is not exposed. However, at this stage, inflow of the plating solution 20 into the through holes 11, which are fine holes having a high aspect ratio and a diameter on the order of several tens of micrometers that pass through the substrate 10 having a thickness on the order of several hundred micrometers, has hardly begun.

[0023]

Once insertion of the substrate 10 into the plating solution 20 has been completed, the inside of the decompression chamber 18 is pressurized. As shown in FIG. 11A, prior to pressurization of the inside of the decompression chamber 18, since a state of reduced pressure in the through holes 11 in which the plating solution 20 is has not flown is maintained by the plating solution 20 and sealing material 17 that cover the openings (openings on the side of the top surface 13) of the through holes 11. Therefore, by pressuring the inside of the pressurization chamber 18, the plating solution 20 is able to reliably flow into and fill the inside of the through holes 11 (see FIGS. 11B and 12). The pressure during this pressurization should be equal to or greater than atmospheric pressure. In addition, at this time, since the wettability of the plating solution 20 is ensured by the metal layer 15 formed on the inner surface of the end portion of each through holes 11 on the side of the bottom surface 14, the plating solution 20 acclimates well with the inner surface of the through holes 11 even in the vicinity of the side of the bottom surface 14 of the through holes 11, and since it is filled without forming voids within the through holes 11, the plating solution 20 can be reliably filled throughout the through holes 11.

[0024]

(Cooling and Solidification Step)

Once filling of the plating solution 20 into the through holes 11 is completed, as shown in FIG. 13, the substrate 10 is lifted out from the plating solution 20. At this time, since openings of the through holes 11 on the side of the bottom surface 14 are maintained in a state of being occluded by the heat-resistant film 17, the plating solution 20 within the through holes 11 does not come out from the bottom surface 14. In addition, there is also no occurrence of the problem of the plating solution 20 filled into the through holes 11 running out from the openings of the through holes 11 on the side of the top surface 13 due to the wettability of the plating solution 20 with respect to the metal film 15 formed on the inner surface near the openings of the through holes 11 on the side of the top surface 13 and around those openings.

[0025]

The plating solution 20 along a metal pattern (made of the metal film 15) formed in the metallization step remains adhered on the top surface 13 of the substrate 10 without falling off after the substrate 10 has been lifted out from the plating solution 20. In areas other than the metal pattern, since the wettability of the plating solution 20 with respect to the substrate 10 is poor, the plating solution 20 drops off accompanying lifting of the substrate 10 from the plating solution 20.

For example, as shown in FIG. 7, in the case a circular metal layer 15 has been formed around the opening of each through holes 11 corresponding to the shape of a bump, the plating solution 20 continuous with the through holes 11 is padded at the areas where this metal layer 15 and the opening of the through hole 11 are present (area where the metal layer 15 is present on the top surface 13 and area where the opening of the through hole 11 is present).

[0026]

Once the substrate 10 is lifted out of the plating solution 20, the substrate 10 is cooled to solidify the plating solution 20 filled into the through holes 11 as well as the above patted plating solution 20. As a result, as shown in FIG. 14, through wirings 22 comprised by solidifying the plating solution 20 in through holes 11, and bumps 23 protruding from the top surface 13, are formed unitarily.

As was previously described, since outflow of the plating solution 20 from the

through holes 11 accompanying lifting out of the substrate 10 from the plating solution 20 is prevented, and the filled state of the plating solution 20 in the through holes 11 can be reliably maintained, the through wirings 22 are reliably obtained without defects such as internal voids. In addition, since the plating solution 20 is a peak shape at the areas where the metal layer 15 and openings of the through holes 11 are present due to its surface tension, as a result of cooling and solidifying the plating solution 20, a peak-shaped bumps 23 are formed protruding from the top surface 13.

[0027]

In this manner, in a constitution in which the through wirings 22 and bumps 23 are formed unitarily, there are no problems such as defective bonding and electrical properties can be reliably ensured as compared with constitutions in which the bumps are formed separately from through wirings and then bonded with through wirings. In addition, there is also no problem of brittleness of bonded sections (bonded sections between the bumps and through wirings) caused by differences in coefficients of thermal expansion or diffusion of materials as occurs in the case of the bumps and through wirings being of different materials, thereby enabling long-term reliability to be improved. Note that the through wiring 22 functions as a filled metal section recited in claim 7 and the bump 32 functions as an external metal section recited in claim 7.

[0028]

FIG. 15 is a drawing of a comparative example in which metal layer 15 is not formed on a substrate, namely only a plating solution filling step and cooling and solidification step are carried out without carrying out a metallization step. In FIG. 15, a substrate 3 is the same as the substrate 10 explained in the present embodiment, and the plating solution indicated with reference symbol 2 in FIG. 15 is the same as the plating solution 20 explained in the present embodiment. In this case as well, although a plating solution 2 has been filled into the entirety of through holes 1 of the substrate 3 in the plating solution filling step, the plating solution flows out from the through holes 1 when the substrate 3 is lifted out from the plating solution in the plating solution bath 19, and as a result, the plating solution 2 was confirmed to be insufficiently filled into the through holes 1, and a level difference D was confirmed to be formed in which the upper surface of the plating solution 2 was several micrometers to several tens of micrometers lower than a surface 4 of the substrate 3 that is the upper side when the

substrate 3 is lifted out of the plating solution 2. On the basis of these results, it is clear that the through wiring forming method as claimed in the present invention demonstrates effects that prevent the outflow of the plating solution by the metal layer 15 formed on the inner surface of the through holes in the vicinity of openings and around the openings of the through holes in the top surface.

[0029]

Furthermore, although the through wiring forming method as claimed in the present invention has also been verified with respect to the case of forming the metal layer only on the inner surface of through holes in the vicinity of openings, but omitting the formation of the metal layer around the openings of the through holes in the top surface of the substrate, although it is difficult to form bumps of adequate size, the outflow of the plating solution from the through holes accompanying lifting of the substrate from the plating solution can be prevented, and there is no occurrence of problems such as the occurrence of a level difference due to insufficient filling of the plating solution. In this case, for example, effects are obtained such as being able to reduce the occurrence of bonding defects to an extremely low level when forming bumps to be bonded with through wirings in a separate step.

[0030]

(Other Examples of Application of Metal Filling Method)

FIG. 26 shows an example of forming a filled metal section 26 and external metal section 27 by employing a work piece in the form of glass rod 24 (hereinafter, work piece may be referred to as the "glass rod") and filling plating solution in the form of tin into a through hole 25 having a diameter of 0.1 mm and total length of 5 mm provided along the axial direction of this glass rod (vertical direction in FIG. 16) using the same technique as the above-described embodiment (by sequentially carrying out a metallization step, plating solution filling step and cooling and solidification step in the same manner as previously described, wherein a side 28 of the upper surface of this work piece 24 to be described later corresponds to the substrate top surface, and the opposite side corresponds to the substrate bottom surface). The type and forming method of the metal layer 15, the heat-resistant film 17 and so forth that are employed are the same as those previously described. However, the range over which the metal layer 15 is formed is the range equal to roughly 2 to 3 times the diameter of the through

hole 25 from both ends in the axial direction of the through hole 25 towards the center in the axial direction, and roughly several millimeters from the outer circumference of the opening around said opening of the through hole 25 on both opposing sides in the axial direction of the glass rod 24.

[0031]

Although the technique for filling the plating solution into the through hole 25 is the same as the plating solution filling step previously described, insertion and removal of the glass rod 24 with respect to the plating solution stored in the plating solution bath 19 inside the decompression chamber 18 is performed with the side on which the heat-resistant film 17 is provided facing downward. In explaining this with reference to FIG. 17 (FIG. 17 shows the state in which the work piece 24 has been lifted out from the plating solution 20), the work piece 24, following completion of formation of the metal layer 15, is attached to the raising and lowering jig 21 inside the decompression chamber 18, and is raised and lowered within the decompression chamber 18 while maintaining the orientation in which the through hole 25 is vertical by raising and lowering of the raising and lowering jig 21. However, the opening of the other end in the axial direction facing downward in opposition to one end in the axial direction of the through hole 25 facing upward when housed in the decompression chamber 18 is covered in advance with the sealing material 17 prior to being housed in the decompression chamber 18. Once this work piece 24 has been housed in the decompression chamber 18, the pressure inside the decompression chamber 18 is reduced, the work piece 24 is lowered while maintaining this reduced pressure state, and inserted in the plating solution 20 stored within the plating solution bath 19 inside the decompression chamber 18. Next, with the work piece 24 still inserted in the plating solution 20, the inside of the decompression chamber 18 is pressurized causing the plating solution 20 to be filled into the through hole 25. Next, the work piece 24 is raised up, lifted out from the plating solution 20 and cooled.

[0032]

In this example as well, similar to the case of the previously described substrate 10, filling of the plating solution throughout the through hole 25 can be carried out reliably. In addition, the plating solution continuous with the through hole 25 is padded on the opening of the through hole 25 on the surface 28 of the upper side of the

work piece 24 that has been lifted out from the plating solution 20 (the side of the work piece 24 in which one end of the through hole 25 is open) and where the metal layer 15 is present around the opening. Therefore, the filled metal section 26, which is comprised by cooling the work piece 24 that has been lifted out from the plating solution 20 followed by solidifying the plating solution 20 within the through hole 25, and the external metal section 27, which is comprised by solidification of the above padded plating solution 20, can be formed unitarily.

As a result, the solid filled metal sections 26 free of voids can be formed. In addition, although the diameter (inner diameter) of the through hole 25 is larger than that of the through holes 11 of the substrate 10 previously described, since the filled metal section 26 is such that the through hole 25 is filled throughout, including one end in the axial direction of the through hole 25, and a level difference is not formed on one end in the axial direction of the through hole 25 such that the end of the filled metal section 26 drops in from the side of the work piece 24, outflow of the plating solution from the through hole 25 when the glass rod 24 is lifted out from the plating solution bath 19 is considered to be prevented in this example as well.

[0033]

Furthermore, the present invention is not limited to the above-mentioned embodiments, but rather can be altered to achieve various variations.

For example, the technique used to form the metal layer is not limited to the above-mentioned sputtering, but rather plating (by inserting the substrate in plating liquid) and so forth can also be employed.

Although a substrate and rod-shaped member were indicated as examples of a work piece in the above embodiments with respect to the metal filling method as claimed in the present invention, the present invention is not limited to these, but rather various types of shapes, materials and so forth can be used for the specific shape, material and so forth of the work piece.

Insertion of the substrate or work piece into the plating solution and lifting out from the plating solution are not limited to being carried out in an orientation in which the side on which through holes are occluded by a sealing material in the form of a heat-resistant film is facing downward as was exemplified in the drawings in so forth, but rather a large degree of freedom is able to be secured for the orientation during

insertion of the work piece in the plating solution and lifting out of the work piece from the plating solution depending on, for example, the wettability between the metal layer formed on the inner surface in the vicinity of openings of through holes and the plating solution that has flowed into the through holes, the fluidity of the plating solution and other conditions.

[0034]

[Effects of the Invention]

As described above, according to the present invention, wettability with the plating solution filled into the through hole is ensured by the metal layer formed on the inner surface of the end opposed to the side in which the sealing material occludes the through hole, among the both ends of the through hole (in the inventions recited in claims 1 and 2, the metal layer is formed on an inner surface of an opening of the through hole on at least one surface of the top surface and bottom surface of the substrate, and in the invention recited in claim 6, the metal layer is formed on an inner surface of at least one end portion of both end portions of the axial direction of the through hole). As a result, when a substrate is lifted out from the plating solution, it is difficult for the plating solution to flow out from the opening of the through hole, and problems can be prevented such as the formation of a level difference near the opening of the through hole. If this level difference is eliminated, bonding can be carried out reliably in the case of bonding bumps and so forth formed in a separate step to through wirings (claims 1 and 2) or filled metal sections (claim 6) and so forth in which this plating solution has solidified, thereby allowing bonding defects to be prevented. In addition, if a metal layer is formed on the inner surface of both ends of the through hole (in claims 1 and 2, the inner surface of the opening of the through hole on both top and bottom surfaces of the substrate), the formation of voids inside the through hole (and especially voids that form easily near the lower end at the time of lifting out) can be effectively prevented, thereby enabling the plating solution to be reliably filled throughout the through hole and allowing the formation of reliable through wirings free of level differences and voids.

According to the invention recited in claim 2, it is possible to reliably fill the plating solution into through holes (fine holes) having a high aspect ratio, and it is possible to reliably form through wirings without level difference.

[0035]

In the invention recited in claim 3, as a result of forming the metal layer on the inner surface of the opening of the through hole on at least one surface of the top surface and bottom surface of the substrate as well as around the opening of the one surface, the outflow of the plating solution from the through hole when the substrate is lifted out from the plating solution can be more reliably prevented due to the wettability of the plating solution with respect to the metal layer around the opening. In addition, when a substrate is lifted out from the plating solution, by taking advantage of the formation of a layer of the conductive metal along this metal layer (metal layer around the opening), wiring grounded sections, bumps and so forth can be formed on the substrate by cooling and solidifying the plating solution on this metal layer.

[0036]

The invention recited in claim 4 discloses a method of forming a bump using the invention recited in claim 3, and the bump is formed by, after the plating solution communicating from the through hole is padded at sites where the metal layer was formed on the inner surface of the opening of the through hole on the one surface and around the opening of the substrate, cooling and solidifying the plating solution. Since this bump is formed unitarily with the through wiring formed by the plating solution that solidifies within the through hole, there is the advantage of the absence of defective bonding and so forth with the through wiring. In addition, there are also no problems such as brittleness of a bonded section (bonded section between the bump and the through wiring) caused by differences in coefficients of thermal expansion or diffusion of materials like those which occur in the case of the bump and the through wiring being of different materials, thereby resulting in improved long-term reliability. When forming the bump according to the invention recited in claim 4, in the formation of the metal layer around the opening of each through hole in the one surface of the substrate, the bump of a target size can be formed easily by patterning the metal layer according to the target shape of the bump to be formed. In this case, the range of formation of the metal layer around the opening of the through hole in the one surface of the substrate can be adjusted by patterning, offering the advantage of being able to easily adjust the height, size and so forth of the bump.

[0037]

According to the metal filling method recited in claim 7, a filled metal section formed by solidification of the plating solution within the through hole, and an external metal section formed by solidification of the padded sections of the plating solution, can be formed unitarily by cooling the work piece which has been lifted out from the plating solution. Therefore, similar effects to those of the invention recited in claim 4 can be obtained.

[Brief Description of the Drawings]

[FIG. 1] FIG. 1 is a cross-sectional view of one embodiment of a through wiring forming method according to the present invention showing the substrate to be used.

[FIG. 2] FIG. 2 is a cross-sectional view showing the state in which an oxide film has been formed as an electrical insulating layer by thermal oxidation treatment of the substrate of FIG. 1.

[FIG. 3] FIG. 3 is a cross-sectional view showing the state in which a metal layer has been formed on the substrate following the thermal oxidation treatment of FIG. 2.

[FIG. 4] FIG. 4 is a cross-sectional view showing the details of the metal layer of FIG. 3.

[FIG. 5] FIG. 5 is a cross-sectional view showing the state in which a photosensitive resist has been applied to the substrate on which the metal layer of FIG. 3 has been formed.

[FIG. 6] FIG. 6 is a cross-sectional view showing the state in which the photosensitive resist has been removed from the substrate of FIG. 5.

[FIG. 7] FIG. 7 is a perspective view showing an example of forming by patterning a metal layer on a substrate surface.

[FIG. 8] FIG. 8 is a drawing showing the state in which the openings of through holes have been covered by affixing a heat-resistant film to the bottom surface of a substrate on which the patterning of the metal layer of FIG. 7 has been completed.

[FIG. 9] FIG. 9 is a cross-sectional view showing a decompression chamber that is applied to the forming method of through wirings as claimed in the present invention.

[FIG. 10] FIG. 10 is a drawing showing the state in which a substrate has been inserted in a plating solution stored in a plating solution bath installed within the decompression chamber of FIG. 9.

[FIG. 11] (a) is a cross-sectional view showing the state in which a substrate has

been inserted in the plating solution after having reduced the pressure in a decompression chamber, while (b) is a cross-sectional view showing the state in which the plating solution has been filled into through holes of a substrate by pressurizing the inside of the decompression chamber.

[FIG. 12] FIG. 12 is a cross-sectional view showing the details of the state of FIG. 11B.

[FIG. 13] FIG. 13 is a drawing showing the state in which a substrate has been removed from the plating solution stored in a plating solution tank installed within the decompression chamber of FIG. 9.

[FIG. 14] FIG. 14 is a cross-sectional view showing the state in which through wirings and bumps have been formed by cooling a substrate that has been removed from the plating solution.

[FIG. 15] FIG. 15 is a cross-sectional view showing the state in which through wirings have been formed in through holes of a substrate by a through wiring forming method of a comparative example.

[FIG. 16] FIG. 16 is a cross-sectional view showing an example of having formed filled metal sections and external metal sections according to the metal filling method as claimed in the present invention in a glass rod containing a through hole.

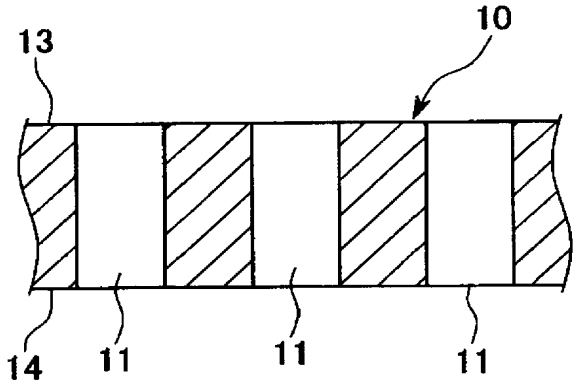
[FIG. 17] FIG. 17 is a drawing of a step in which the plating solution is filled into the through hole of the glass rod of FIG. 16 that shows the state in which a substrate has been removed from the plating solution stored in a plating solution bath installed inside a decompression chamber.

[Brief Description of the Reference Symbols]

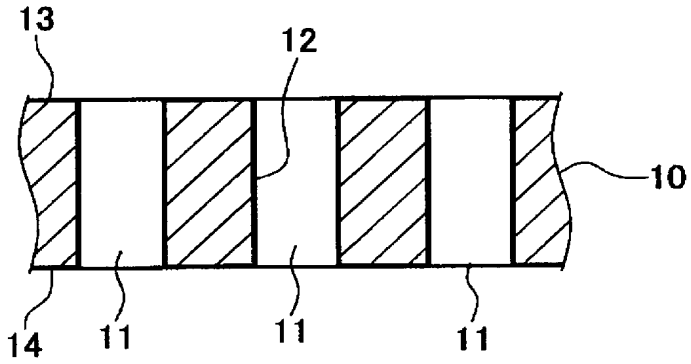
10: substrate; work piece, 11: through hole, 13: top surface (one surface), 14: bottom surface (the other surface), 15: metal layer, 17: sealing material (heat-resistant film), 18: decompression chamber, 19: plating solution bath, 20: plating solution, 22: through wiring; filled metal section, 23: bump; external metal section, 24: work piece (glass rod); 25: through hole, 26: filled metal section; 27: external metal section, and 28: upper side surface.

[Document Type] Drawing

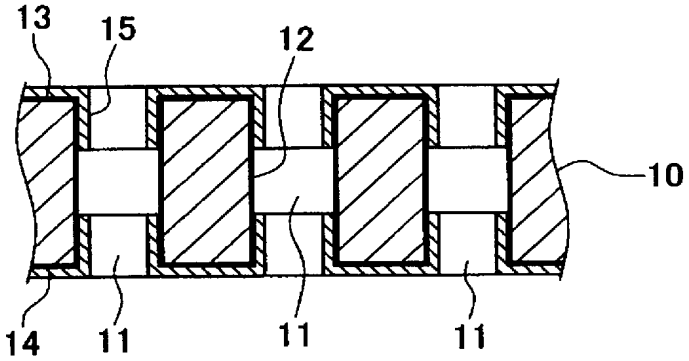
[FIG. 1]



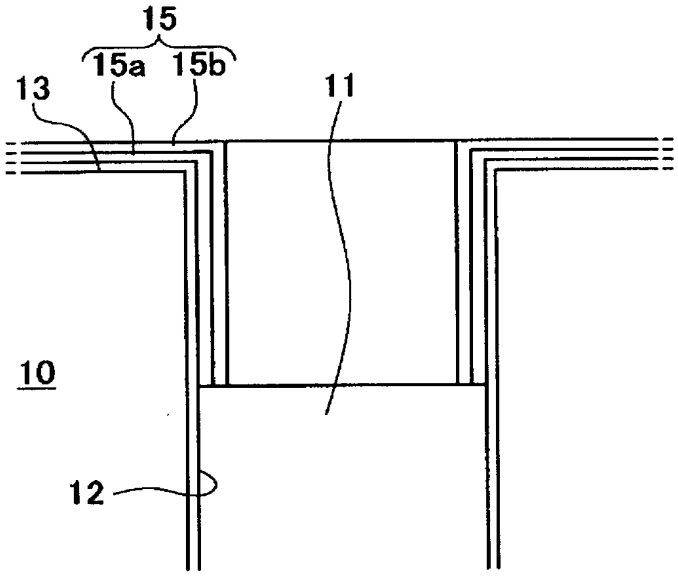
[FIG. 2]



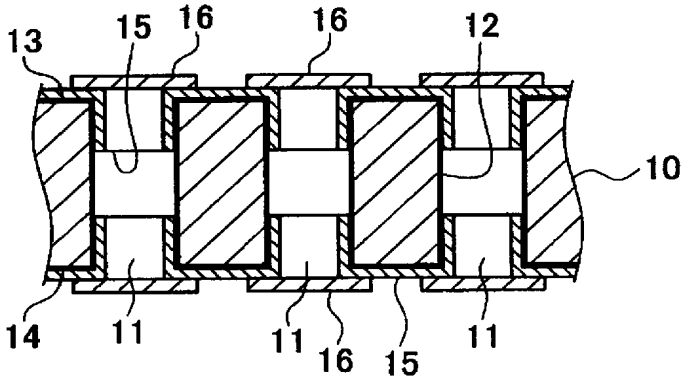
[FIG. 3]



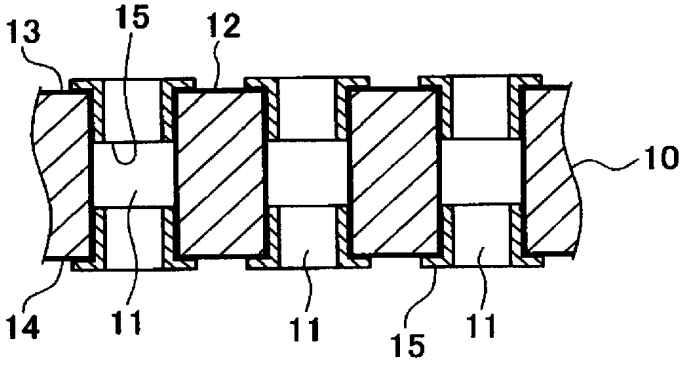
[FIG. 4]



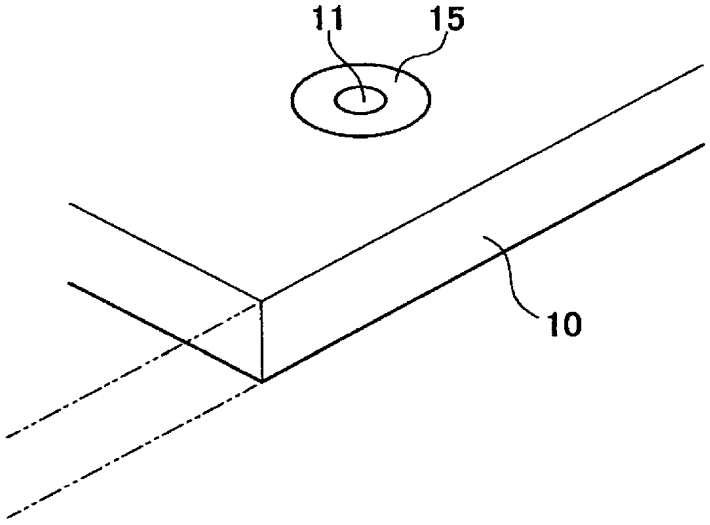
[FIG. 5]



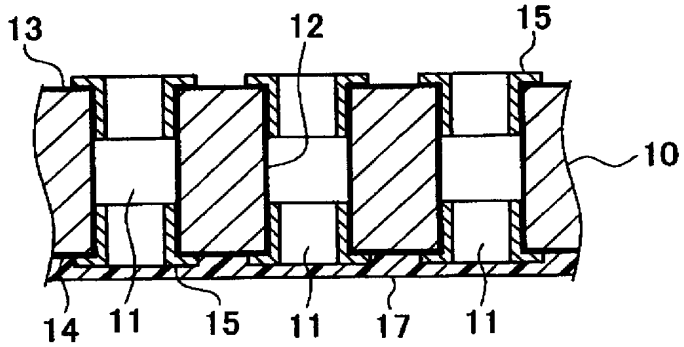
[FIG. 6]



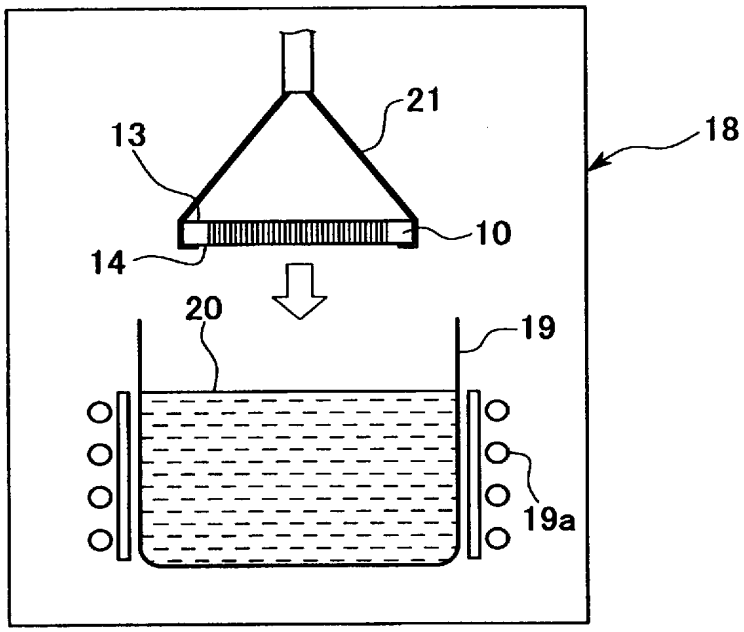
[FIG. 7]



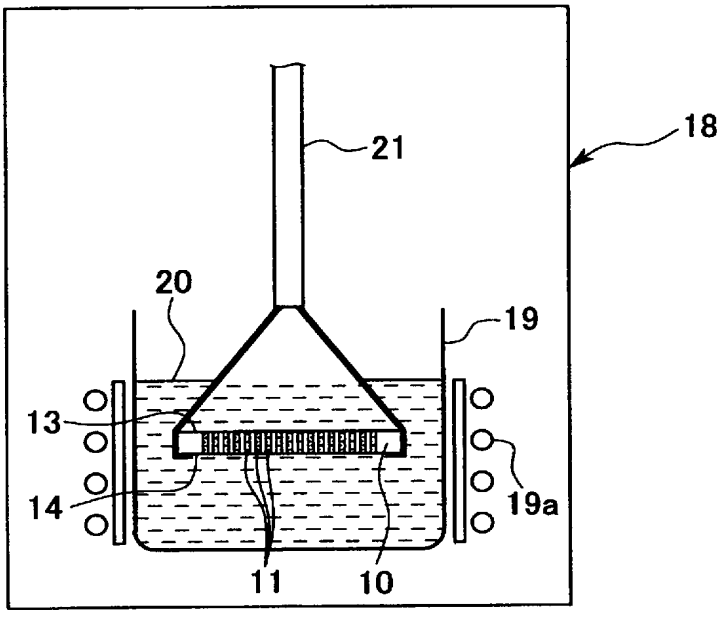
[FIG. 8]



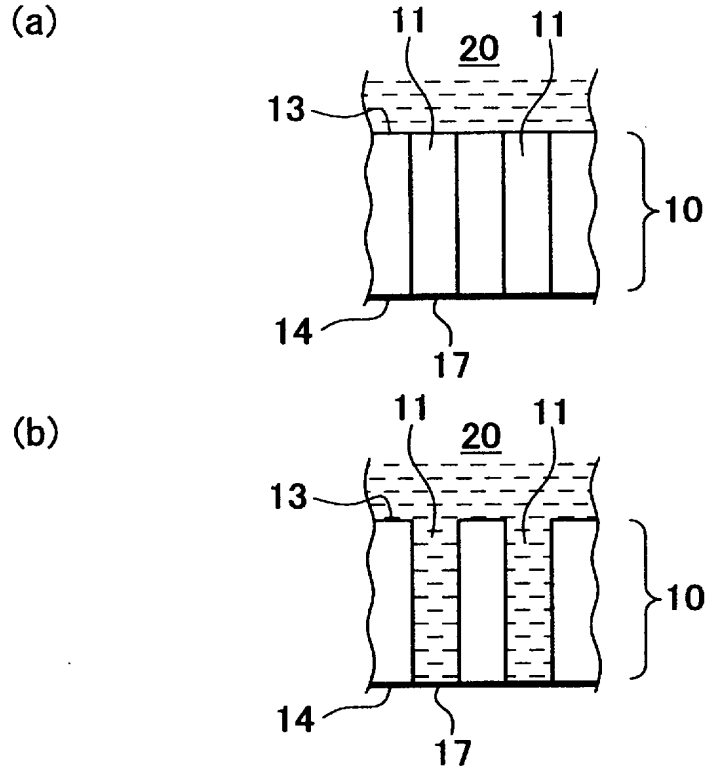
[FIG. 9]



[FIG. 10]



[FIG. 11]


(a)
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20
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(b)
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20
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13
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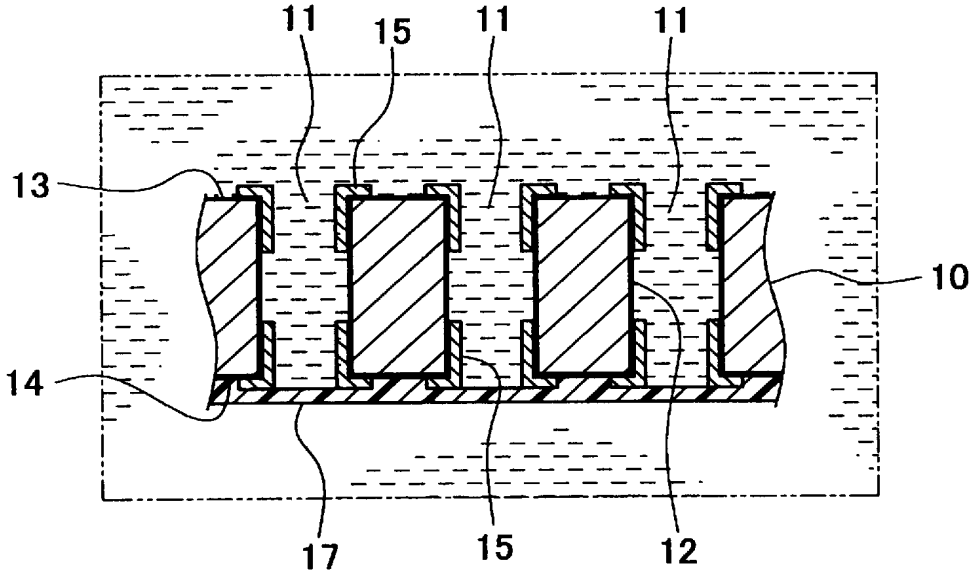
14
17

[FIG. 12]


11
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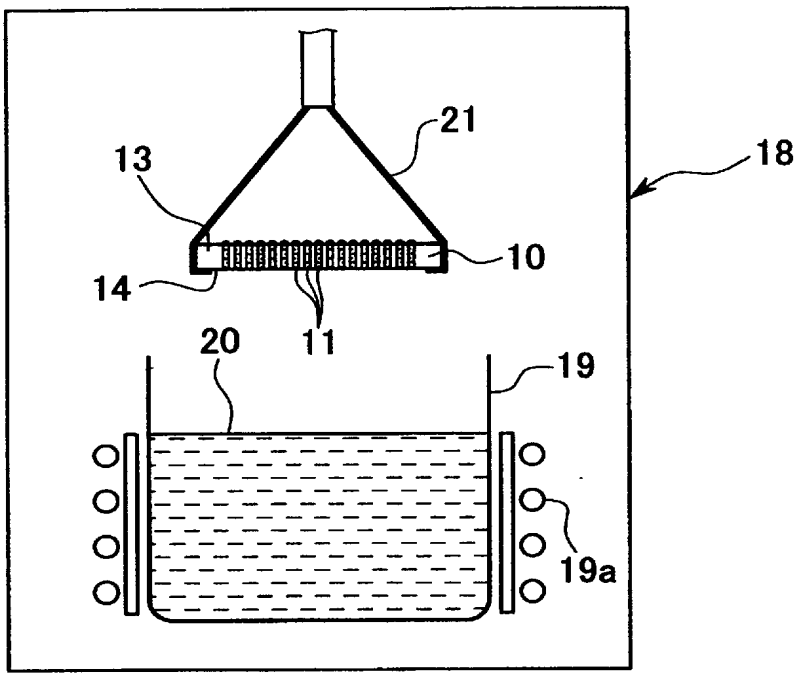
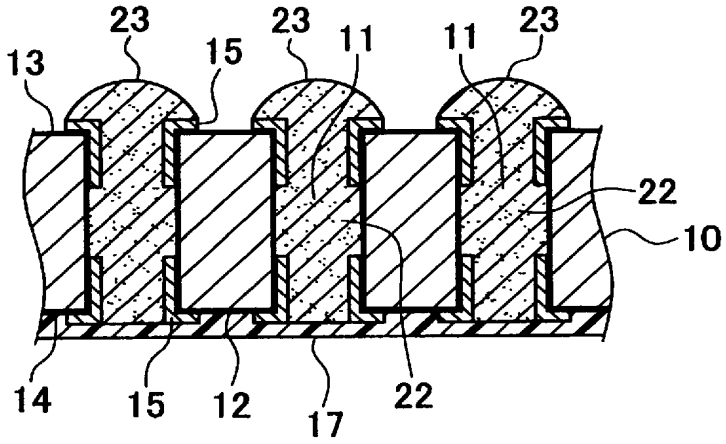
15
12

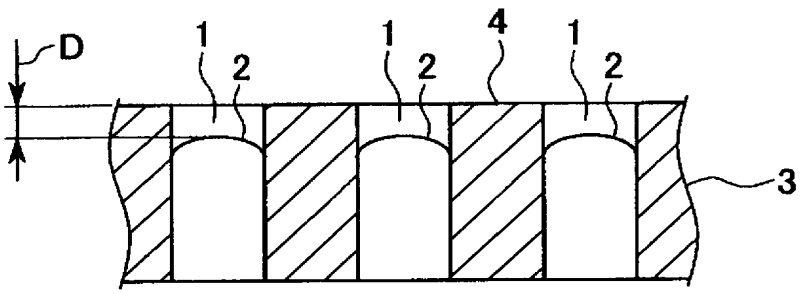
[FIG. 13]



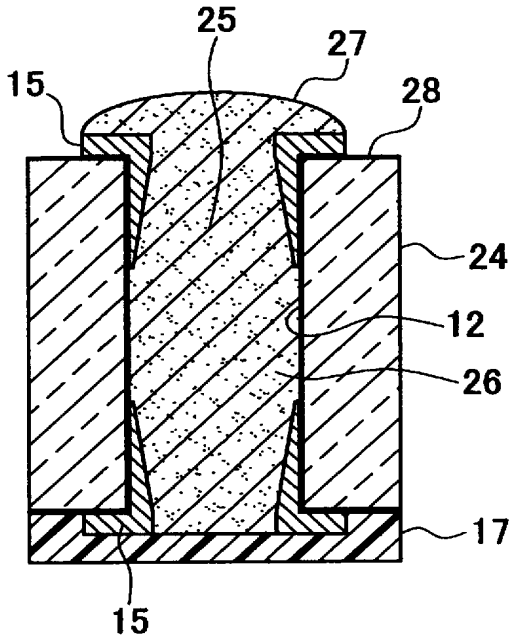
[FIG. 14]



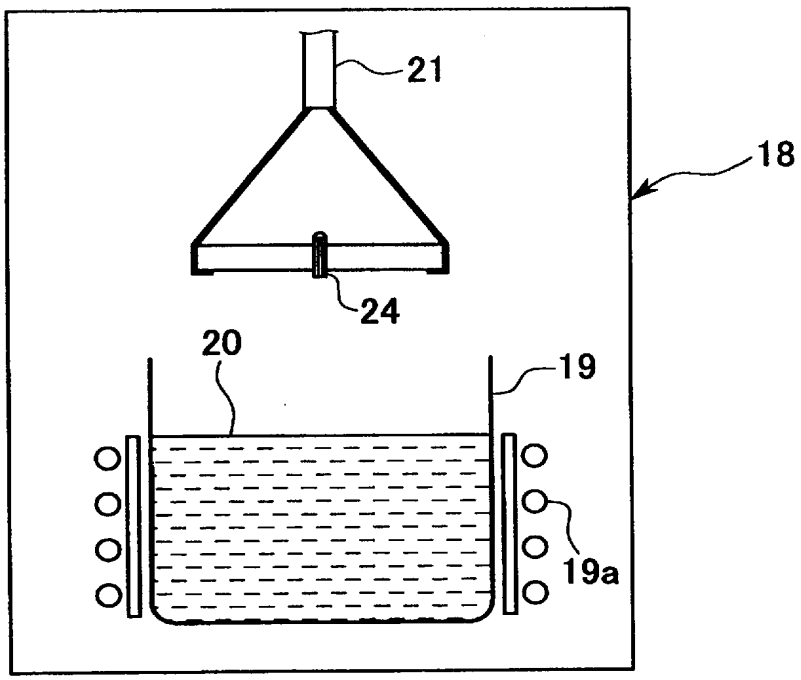
[FIG. 15]



[FIG. 16]



[FIG. 17]



[Document Type] Abstract

[Abstract]

[Problem to be Solved by the Invention] In the formation of through wirings in a silicon substrate and so forth, there was a need for the development of a technology that would allow metal to be reliably filled particularly in the vicinity of openings of through holes.

[Means for Solving the Problem] This invention provides a through wiring forming method and a metal filling method in which, in the inflow and filling of a plating solution into through holes 11 of a substrate 10 by inserting said substrate 10 in heated and melted conductive metal, a through wiring is formed by preliminarily forming a metal layer 15 on the inner surface of one of the ends of through holes 11 of the substrate 10 as well as on the substrate top surface 13 around the opening, lifting out the substrate 10 on which inflow and filling of the plating solution into through holes 11 has been completed from the plating solution, and then cooling to solidify the plating solution that has been filled into the through holes.

[Selected Drawing] FIG. 8

Patent Application No. 2001-287082

Information on Applicant

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(Reason)	Change of Name
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